# Resin a toast to fossil-rich amber

## Ambers from Gujarat reveal ancient secrets of the Earth.

REKHA DIXIT

Hukam Singh's workplace is stashed with amber. Much of it is raw, in fist-sized chunks. Some pieces are like paperweights, polished to a smooth finish. Yet other bits have been pared to slivers, offsetting their translucency. When seen in clear light, these pieces often reveal remains of life from millions of years ago — a scrap of fungus, some ground dirt, the broken leg of an insect, or a part of its wing. Occasionally, an entire arthropod, flower, or leaf is preserved. All these provide a window into the Eocene, a time when the Earth was much warmer than it is today, and the continents were still drifting.

Singh — who heads the Amber Analysis and Palaeoentomology Laboratory at Lucknow's Birbal Sahni Institute of Palaeosciences (BSIP) — recalls the first piece of amber he held 20 years ago. A young researcher then, he was at a dig at the Vastan Lignite Mine in Khambhat (Cambay) in Gujarat, looking for vertebrate fossils with his guide, R.S. Rana. The area is a trove of fossils, with scientists having recovered remains of molluscs, amphibians, reptiles, and large mammals (*bit.ly/cambay-fossils*).

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### Abundant deposits

He came across an unusual-looking rock, some 5 cm in length. "We showed it to Ashok Sahni, the famous palaeontologist from Panjab University, Chandigarh, who was with us at the dig. He immediately identified it as amber," recalls Singh. "I myself had no idea what amber even was," he adds.

Amber is fossilised tree resin, exuded for self-defence and healing. The defence could be against infection or infestation. Physical injuries to the tree are also treated with resin, which oozes out to coat cuts and wounds, much like platelets form a scab. Resin is sometimes secreted as a response to abiotic stress, such as excessive heat or an extreme climatic event. The resin trickles down the bark, falling in globs on the forest floor, trapping detritus and small creatures. When preserved in moist, oxygen-free sediments, these deposits gradually lose their volatile compounds and polymerise into a harder, inert substance. Even with the right conditions, it takes several million years for resin to turn into amber.

Hukam Singh and Priya Agnihotri collecting amber from a lignite mine in Kutch.

COURTESY: HUKAM SINGH

Amber is found on every continent – even in Antarctica, where it was discovered recently (*bit.ly/antarctica-amber*). The oldest amber, from 300 million years ago, consists of tiny flecks of fossil resin found in a coal seam in Illinois, U.S. The most commonly occurring amber is from the resins of coniferous trees. In India, however, angiosperms, mainly the dipterocarps group of trees, are the source of amber.

The initial discovery led to the first research paper on amber in India (*bit.ly/first-record*). Sahni, understanding the potential of the find, embarked on an amber expedition, sometime around 2008-09, with a team of international researchers, including David A. Grimaldi, Curator at the American Museum of Natural History, New York, and author of *Amber: Window to the Past*. Grimaldi recalls his astonishment at the size of the lignite mines and the amount of amber there. In his experience, expeditions can turn disappointing, with teams uncovering dispersed or poorly preserved amber. Sometimes, a site may have plenty of amber but no fossils.

Cambay was different. The deposits were abundant, with "chock-full of arthropods" embedded in them. "Many tonnes of amber are excavated from each mine annually, a tiny portion of which is collected for palaeontological studies," he says. Grimaldi recalls an administrator at a mine saying that the fossil resin (which readily burns) contributed about 10% of the total energy from the mine.

A pseudoscorpion with well-developed pincers preserved in a piece of Cambay amber.

HUKAM SINGH

The expedition brought back around 150 kg of amber, from which the team identified 100 arthropod species, as well as numerous species of fungus and plant spores. Their 2010 study (*bit.ly/Cambay-amber*) identified Cambay amber as the oldest evidence of tropical forests in India and put the date of dipterocarps, from which the amber was formed, as much older than previously thought. Dipterocarps account for around 80% of trees in the rainforests of South Asia. "My career took a completely different turn with that discovery. From studying sediments and vertebrates, I began understanding resin chemistry and palaeoentomology," Singh says.

### Tales fossils tell

A tiny fossil can reveal a lot. A few years ago, Singh's team worked on identifying a 2-mm-long flower in Cambay amber. They identified it as one of the earliest known species of Rauvolfioids (a sub-family that includes oleander and plumeria) and also suggested the likely pollinators of this tiny flower from the assemblage of insects co-occurring in the amber. Thus, from tiny specks, they recreated the buzzing life on an ancient tree (*bit.ly/flower-amber*). "Although we do not know the original colour of the flowers, the number and arrangement of stamens, and the kind of nectar glands, can help (in deducing pollination biology)," says the study's co-author Steven R. Manchester, Curator of Paleobotany, Florida Museum of Natural History. Manchester is now working on identifying another well-preserved flower, 5 mm long, which is "certainly a new species for the fossil record".

Singh presides over a laboratory equipped with modern devices for cutting, polishing, and scanning amber. This laboratory, inaugurated in November 2023, is a huge upgrade from the painstaking way the team manually prepared amber for study, using an emery sheet to polish the samples. Much of the cutting and analysis that had to be sourced to overseas institutes can now be done in-house, speeding up research, says Singh, pointing to the cupboards crammed with boxes labelled 'Not yet analysed'.

"Working on this collection alone should keep a team of researchers busy for years," says BSIP Director Mahesh Thakkar. A micro-CT scanner is about to join the institute. "This machine, which can give high-precision, slice-by-slice 3D images of an object, will help with high-quality scanning in-house," he adds. Such imaging was done at collaborating institutes or industrial facilities.

The world's most diverse palaeobiotas preserved in amber are the Baltic amber (Eocene), Kachin amber from northern Myanmar (mid-Cretaceous), and Miocene Dominican amber. "Baltic amber has been studied for centuries; Myanmar and

### Beyond Gujarat

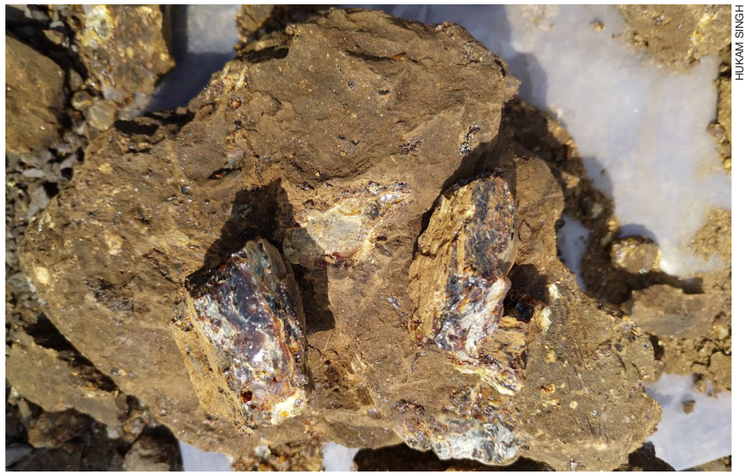
Researchers in India are looking at new prospective sites for amber troves. Potential sites include lignite mines in Rajasthan's Barmer and Nagaur districts and Neyveli in Tamil Nadu. "There are reports of copal found at Neyveli, but we need to explore if there are fossils in them," says Singh. Copal is an intermediate stage between resin and amber and is much younger than the latter, dating back several thousands of years instead of millions. Some amber blebs have also been discovered in Mizoram. Suryendu Dutta, Professor in the Department of Earth Sciences at the Indian Institute of Technology Bombay, studied their resin chemistry and found that the amber-producing trees of the Miocene epoch (23 million to 5.3 million years ago), were not too different from their modern-day descendant, the sal tree. (*go.nature.com/4hYqNbt*). In another bleb, he describes a fossilised Bauhinia leaf (*bit.ly/leaf-mizoram*).

Amber-producing trees of the Miocene epoch were not very different from the sal tree.

Dominican amber for decades. Given several decades of intense study, Indian amber will probably be on par with Baltic and Myanmar amber in species diversity," says Grimaldi.

Within a year of the lab's establishment, Singh's amber department has published two research papers, with most of the scanning and analyses done in-house. These are the identification of an extinct mite from the Kutch amber deposits (*bit.ly/mite-fossil*) and a pseudoscorpion, the smallest known adult, from the Cambay reserves (*bit.ly/pseudoscorpion-fossil*). Every new species identified adds further detail to the tapestry of life in those ancient forests that the amber department is reimagining. The pseudoscorpion had exceptionally developed pincers for phoresis or hitching a ride onto a furry animal. "This is indirect evidence that mammals existed in these forests," says one of the authors of the research papers, Priya Agnihotri.

Although classified as a thorn scrub and grassland today, Kutch was a swampy marshland with humid evergreen forests 47 million years ago. This could be why this amber is so fossiliferous. Some of the plants identified, mostly through pollen and spores, are palms, ebony and dogbanes, ancient relatives of silk cotton, orchids, baobab and sal trees, varieties of grass, tree ferns, and several fungi. "It was quite similar to the rainforests of present-day Borneo," Agnihotri says.



HUKAM SINGH

Raw amber chunks found in Kutch, Gujarat.

**These fossils were formed during a critical period in the history of life. Fossil records provide unique data on the dispersal of arthropods at the time.**

After the amber hoard from Cambay, Sahni suggested that researchers explore the lignite mines of Kutch, too. Amber is often found near or with coal deposits, as the same processes that turn trees into coal fossilise resin to amber. "We recovered around seven sack-loads from the first Kutch expedition in 2018," reminisces Singh. "I hauled most of them to the campsite on my back. A field researcher has to do a lot of things," he says wryly. The amber from Kutch is younger than the Cambay deposits by a few million years. It is darker and has more air bubbles, which make it unclear. However, it is richer in biota.

## Indian speciality

Indian amber may not be jewellery grade, but it is scientifically special for many reasons. Several deposits were formed when the Indian landmass collided with mainland Asia, a time known as the Eocene epoch of the Cenozoic era. So, fossil records provide unique data on the spread and dispersal of arthropods at the time.

For a million years before the event, the Indian landmass was drifting northwards, time long enough for the evolution of insular biota. Fossil evidence, however, questions the premise. Many arthropods in Indian amber show a direct connection to those in Baltic amber, indicating that India was not as isolated as was initially believed. Land bridges may have been one way for the movement of biota.

These fossils were also formed during a critical period in the history of life: the Paleocene-Eocene Thermal Maximum, a very hot and wet period on Earth when there was no ice, and even the poles sustained tropical and subtropical flora and fauna. "Most likely, there were more species of plants and animals in the Eocene than there are now. These amber deposits are the most diverse record of early tropical forests from Asia," says Grimaldi. "This is all important to understanding how climate affects biodiversity and evolution," he adds.

What caused these forests to exude resin in such huge quantities? "We are still guessing the various scenarios," Singh says. "There might have been a biotic or abiotic stress which caused the exudation," he reasons. Was it some geological event, or an exceptional warming event? Or some disease? The resins were exuded copiously for a short span. "The event that caused it may not have lasted more than 15 years," he believes.

The answer to this question, as well as to many other secrets, may be lying within the amber haul in the lab, waiting for researchers to reveal them. •

## Out of amber

**Most ambers are formed from sesquiterpenes that gradually and extensively, over millions of years, become crosslinked, so they cannot be dissolved easily. The Indian amber is a "dammar II" type of resin with a backbone of cadinene, and it does not crosslink readily. Such amber can be dissolved in organic solvents. So, when researchers come across a commonly found fossil, or when the amber is too unclear for studying the fossil, they often dissolve the amber. This is tricky, for the fossil can disintegrate in the process. Even when exposed well, the fossil may still get damaged, as it has to be carbonised before it is studied under an electron microscope. "We take several images of the specimen under a light microscope for the record, before dissolving the amber," says researcher Priya Agnihotri, who specialises in arthropods in amber. Pollens and spores, which are abundant, are extracted by dissolving the amber.**